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(71) Applicant : GENERAL ELECTRIC COMPANY
1 River Road
Schenectady, NY 12345 (US)

(72) Inventor : Perkins, Roger Johnson
3561 Horncastle Drive
Cincinnati, Ohio 45241 (US)
Inventor : Hillery, Robert Victor
8207 Lakespring Court
West Chester, Ohio 45069 (US)
Inventor : Farr, Howard John
9501 Raven Lane
Cincinnati, Ohio 45242 (US)

(74) Representative : Pratt, Richard Wilson et al
London Patent Operation G.E. TECHNICAL SERVICES CO. INC. Burdett House 15/16 Buckingham Street
London WC2N 6DU (GB)

(54) Abrasive turbine blade tips.

(57) A method for applying a thin layer of uncoated abrasive particles (20) to the tip of a turbine blade. A single layer of particles (20) and a thin layer of metal (36) are first deposited on the tip (14). A metal matrix comprising a fine alloying powder and a metal is then deposited over the first thin metal layer and the particles using co-electrodeposition. The turbine blade is then thermally treated to homogenize the thin layer and the codeposited layer containing alloying powders and metal.

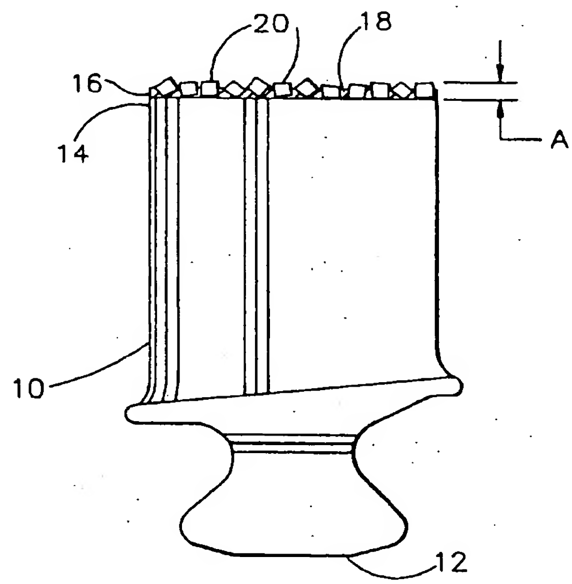

FIG. 1

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Background of the Invention

The performance and efficiency of aircraft gas turbine engines are critically affected by the clearances that exist between the rotating and stationary components in the turbine. Thermal energy from the combustion of fuel in the combustor is converted into mechanical energy through an expansion process by impinging the hot gases of combustion onto a bladed rotor. As the clearances between the rotating bladed rotor and stationary, adjacent assemblies, such as the shroud, increase, the efficiency of the turbine decreases. It is thus desirable to maintain the clearances between the blades of the rotor and the shroud at a minimum without interfering with the rotation of the rotor.

Among the factors affecting the clearance between the rotor blades and the shroud are erosion of the blade due to impingement of the hot combustion gases and removal of blade tip material due to shroud contact during engine operation.

Contact of the blade tip with the shroud or stator life is frequently referred to as rubbing, and occurs most frequently during early engine life. These rubs are attributed primarily to transient thermal and mechanical strains occurring during rapid changes in thrust level due to fast heat-ups, fast cooldowns also referred to as reburst cycles and in reheats.

Thermal expansion results because the rotor has less cooling than the shroud. During rapid increases in thrust levels, at which time additional combustion is occurring, the rotor thermally expands faster than the shroud. Thus, a component of the overall expansion is attributed to the thermal expansion of the rotor in excess of the stator or shroud.

The rotation of the rotor also results in some expansion which also induces mechanical strain. This is another component of the overall expansion of the rotor. When rotor expansion due to the combination of thermal expansion and mechanical strain exceeds the clearance between the rotor and the shroud during fast heat-ups and reburst cycles, rubbing occurs. If, in addition to the shroud wearing away the blade tip thereby shortening the blade, a portion of the shroud is also worn away, an additional undesirable clearance increase occurs which further reduces engine efficiency after the engine returns to normal operating conditions following the heat-up or reburst excursion.

Another cause of rub are maneuvering loads, which are mechanical forces resulting from loadings such as high G-turns, landings and severe turbulence. Unlike rub which is a result of thermal cycling and most frequently occurs in early engine operation, this rub occurs throughout engine life.

All successful turbine tips have the capability of abrading the cooperating turbine shroud as incursions occur during initial engine operation. Examples of such blade tips are described in U.S. Pat. No. 4,744,725 to Eaton et al., U.S. pat. No. 4,232,995 to Stalker et al. and U.S. Pat. No. 3,199,836 to Moyer.

Because the abrasive material is not a structural material, and because its weight imposes stresses on the blade substrate as the blade rotates at high speeds, it is desirable to maintain the abrasive layer to the minimum possible thickness while retaining abrasive capability. Thus, structures such as described in Stalker et al., U.S. Pat. No. 4,232,995 and Eaton et al., U.S. Pat. No. 4,744,725, containing a single layer of abrasive particles embedded in a matrix are preferred to multi-layered tips such as described in Moyer, U.S. Pat. No. 3,199,836.

New and improved methods of applying thin layers of abrasive material to the tips of turbine blades are required. Several methods for application of thin layers of abrasive materials to turbine blades have been proposed.

An example of such a method is described in U.S. Pat: No. 4,744,725 to Eaton et al. This method requires the cladding of ceramic particles with a metal, such as nickel, and then bonding them to the surface requiring the abrasive material with adhesive. The adhesive, which holds the particles in place, is then driven off at elevated temperatures as the nickel cladded particles are bonded or sintered to the substrate at elevated temperatures. Owing to the irregular shape of the particles and the thinness of the metallic cladding on the particles, the bond is relatively delicate. It is also necessary to carefully control the sintering or bonding temperature, as it is undesirable to expose the substrate blade to temperatures which are too high, as changes to the microstructure and mechanical properties may occur. After bonding, the particles are then oversprayed with a layer of matrix material deposited by plasma arc spraying.

Another example of a method of applying thin layers of abrasive materials is described in U.S. Pat. No. 4,169,020 to Stalker et al. This method requires the elevated temperature diffusion bonding of an oxidation-resistant, sulfidation-resistant and thermal fatigue-resistant alloy inner tip to the substrate material. Then, an outer tip portion comprising a metal matrix entrapping a plurality of protruding abrasive particles is applied by electrodeposition.

U.S. pat. No. 4,689,242 to Pike discloses another method of applying metal-coated ceramic particles to a metallic substrate. This method r quires the d position of a multiple lay r coating on each particle, the lay rs comprising a first oxide layer and a second metal layer capable of diffusing into the article surface. The substrate

is coated with a binder solution consisting essentially of a low viscosity carrier liquid, a thermoplastic resin and metal particulates substantially small r than the ceramic particles. A single lay r of the ceramic particles are then disposed on the coated substrate. The article is then heated to diffuse a portion of the metal coating on each ceramic particle and to diffuse the particulates in a contact region into the metal coating and into the article surface, thus securely bonding each particle to the surface. This pr cess reli s on capillary action to draw the metallic coated ceramic particles to the substrate surface as well as sintering to diffuse the metal from the coated particles and from the coating into the substrate surface while driving off the thermoplastic binder. After sintering, a matrix metal is applied over the sintered ceramic particles to fill in spaces between the particles. This matrix is then simultaneously heated and presses to eliminate any voids which may be present and to securely bond the matrix to the substrate by interdiffusion.

In still another method disclosed in U.S. Patent No. 4,854,196 to Mehan, a method of applying aluminum oxide abrasive to the tip of a turbine blade by first coating the aluminum oxide particles with platinum is disclosed. The coated particles are then entrapped in the blade tip by introducing the particles into a molten pool formed by melting a portion of the tip by laser melting. A problem with this method is the cost of platinum.

There is a need for simplified methods of applying thin layers of materials containing environmentally resistant abrasive particles in a metal matrix to the surfaces of substrates which eliminates the necessity of precoating the abrasive articles prior to bringing them in contact with the substrate surface. It is also highly desirable to minimize or eliminate altogether elevated temperature treatments of heat-treatable substrates during the application of abrasive tips since such treatments, if not carefully controlled and monitored, may alter the microstructure of the substrate, hence affecting its mechanical properties and associated performance in service.

SUMMARY OF THE INVENTION

An advantage of the methods of the present invention is that thin coatings of materials containing abrasive particles may be applied to the surface of a metallic substrate without first precoating the abrasive particles. The expensive and time consuming step of coating abrasive particles prior to bringing them in contact with the surface of the substrate can thus be eliminated.

Another advantage of the present invention is that a thin, abrasive tip having a very high volume fraction of hard, ceramic particles for cutting the stator or shroud of a turbine may be applied to a turbine blade tip, thereby reducing the total thickness of the abrasive tip on the blade, and which may subsequently be lost to oxidation, thereby further decreasing rotor diameter.

A further advantage of the methods of the present invention is that thin coatings of materials containing a single layer, or multiple layers of abrasive particles, each layer forming a distinct plane parallel to other planes or layers and to the substrate surface may be applied, if desired.

Still a further advantage of the present invention is that a thin coating of materials containing abrasive particles may be applied to heat treatable substrates, such as nickel base superalloy turbine blade tips, while minimizing the exposure of the substrate to thermal treatments.

In accordance with the present invention, an improved method for applying an abrasive layer to a metallic substrate is provided. The abrasive layer is comprised of abrasive particles having improved environmental resistance in a metal alloy matrix material. The abrasive particles should be approximately coplanar and should have about the same aspect ratio, although different aspect ratios can be used.

The method for applying the abrasive layer to the metallic substrate comprises first selecting abrasive particles having about the same size and shape. The abrasive particles are then brought into physical contact with the substrate surface, while maximizing the volume fraction of particles on the surface. While the substrate to be coated and the abrasive particles are maintained in contact, a thin layer of a first metal is metallurgically deposited onto the surface of the substrate. This thin layer of metal forms a bond with the metallic substrate surface, while simultaneously entrapping the abrasive particles in position against the substrate surface, thereby adhering the abrasive particles to the surface. Because the thickness of this thin layer of the first metal is small in comparison to the size of the particles, the particles are not completely embedded in the thin layer by the deposition method. Finally, a second metal layer which may be comprised of the same metal as the first metal layer, or which may be comprised of a second metal distinct from the metal of the first layer, is applied over both the first thin metal layer and the particles. This second metal layer further has a distribution of fine alloying particles or powders which, following a heat treatment, forms on the metal substrate an abrasive layer having abrasive particl s embedded in a substantially homog neous or near homogeneous alloy metal matrix.

Other f atures and advantages of the pres nt invention will be apparent from the following mor detailed description of the preferred embodiment, taken in conjunction with the accompanying drawings which illustrate, by way of xample, the principles of th invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross-sectional view of a turbine blade having a tip formed of a single lay r of substantially cubic-shaped abrasive particl s embedded in a metal matrix.

Fig. 2 is a cross-sectional view of a pi ce of felt having an adhesive layer with abrasive particles applied, prior to removing excess particles.

Fig. 3 is a cross-sectional view of a piece of felt having an adhesive layer with abrasive particles applied, after removing excess particles.

Fig. 4 is a cross-sectional view of particle-bearing felt in physical contact with a turbine blade tip.

Fig. 5 is a cross-sectional view of particle-bearing felt in contact with a turbine blade tip after application of a a thin metal layer to the blade particle interface.

Fig. 6 is a cross-sectional view of a turbine blade tip having a thin metal layer bonded to the tip, with particles embedded in the layer and adhering to the tip as the adhesive-layered felt is peeled from the tip.

Fig. 7 is a cross-sectional view of a turbine blade tip after the adhesive-layered felt has been removed from the tip, but prior to deposition of the metal matrix.

Fig. 8 is a cross-sectional view of a turbine blade having an environmentally-resistant material which underlies the abrasive tip.

Fig. 9 is a cross-sectional view of a turbine blade having a tip formed of two layers of substantially cubic-shaped abrasive particles of substantially the same size embedded in a metal matrix.

DETAILED DESCRIPTION OF THE INVENTION

An abrasive tip is applied to the tip of a turbine blade, such as those used in aircraft engine applications. The tip is used to maintain a minimal clearance between the blade and the adjacent shroud or stator. During the early life of the engine, the tip rubs against the shroud, particularly during fast heat-ups and reburst cycles. Later in engine life, rub primarily occurs as a result of maneuvering loads. It is thus desirable for the abrasive tip to have a cutting ability while being held to the minimum practical thickness. Also, because of the harsh environment, it is desirable for the blade tip to have good environmental resistance.

The metal removal mechanisms involved in the removal of adjacent shroud material by the turbine blade tip during engine operation are unique because of the high temperatures, high surface speeds and low incursion rates associated with engine operation. Such conditions preclude the machining of chips which is the optimum stock removal route in conventional machining technology.

Analysis of the abrasive tip/metal shroud interactions at engine temperatures, tip speeds and machining rates indicate that the objective is to apply an abrasive and wear resistant material in a configuration which will, when rubbed against the shroud, cause the controlled transfer of shroud material to the blade tip system by abrasive wear. Blade tip speeds may be as high as about 1400 feet per second. Additionally, blade incursion on the shroud may be as high as 2 mils per incursion. There may be about a $4x10^{-9}$ to $8x10^{-9}$ inch incursion of the blade into the shroud per revolution of the bladed rotor during an incursion. At these tip speeds and incursion rates, no large metal chips are formed.

During initial engine operation, as the tip contacts the shroud, the metal is plowed aside by the abrasive particles, although little metal actually breaks free from the shroud. The plowed metal is trapped between the blade tip and the shroud. This removal of shroud material by the blade tip and subsequent entrapment of the removed metal between the tip and shroud (and continued removal of shroud material by plowing action) is known as abrasive wear. Large, angular abrasive particles in marked relief from the metal matrix are desired during this stage.

After this initial rub, metal may be removed from the shroud by secondary adhesive wear, that is, wear due to welding of contacting asperities.

Referring now to Fig. 1, a turbine blade 10 having a dovetail end 12 and a tip end 14 is depicted. An abrasive tip 16 comprised of a metal matrix material 18 and preferrably a single layer of abrasive particles 20 of approximately the same size is attached to tip end 14 which forms the substrate.

The abrasive particles 20 are oxidation-resistant, corrosion-resistant and preferrably non-conducting. These particles are preferrably alumina, Sialon, $Si3N_4$ or refractory metal carbides such as chromium carbide, tantalum carbide, niobium carbide or tungsten carbide.

Th abrasiv particl s 20 should be generally cubic or cuboidal in shape, thereby having an aspect ratio of about 1, although other shap s may be us d. If oth r shapes are used, the particles should have th same aspect ratio. The cubic shaped particles are preferred because this configuration provides for optimum packing density of particles on th blade tip, thus maximizing th ir volume fraction. Th siz of the particles may vary from about 2 mils to about 15 mils on an edge, with the edge size being approximately the same (ie. about ±

1 mil) in the size selected, although particles having an edge size of about 5-6 mils are most preferred.

Although cubic or cuboidal particles may be made by any effective process, it has been found that the Sol-Gel process produces a high concentration of cuboidal or cubic particles of the desired size. Materials produced by this proprietary process may be obtained from the 3-M Co. or the Norton Co.

After s lecting particles of an appropriate size and shape, the particles are brought into physical contact with the metal substrate. Referring now to Fig. 2, a piece of felt 30 having an adhesive layer 32 on one surface 34 is brought into contact with selected abrasive particles 20. Abrasive particles 20 adhere to adhesive layer 32 on one surface 34 of felt 30. Abrasive particles 20 may form more than one layer over adhesive layer 32 as shown in Fig. 2. Because only a single layer of particles is preferred, excess particles may be removed from the felt by any known method, such as by shaking or blowing with an air stream sufficient to remove particles not contacting the adhesive without affecting those in contact with the adhesive, resulting in a single layer of abrasive particles 20 adhering to adhesive layer 32 as shown in Fig. 3. Referring now to Fig. 4, particles 20 are brought into physical contact with tip end 14 of blade 10.

While maintaining particles 20, adhering to adhesive layer 32 of felt layer 30, in physical contact with the substrate, depicted as tip 14 of blade 10 in Fig. 5, a thin layer of metal 36 is metallurgically deposited onto tip 14. Although any known method of maintaining contact between tip 14 and particles 20 may be used, it is preferred that a fixture (not shown) be used. The fixture holds the blade in contact with the particles adhering to felt layer 30 during deposition of layer 36. The force applied to assure solid contact between the tip 14 and the particles 20 may be supplied by gravity, by spring loading, clamping, or by any other suitable means.

Layer of metal 36, applied on the substrate, at tip 14 of Fig. 5, physically is located between tip 14, to which it is metallurgically attached, and adhesive layer 32 on felt layer 30. Thin metal layer 36 also at least partially entraps abrasive particles 20 thereby causing them to adhere to tip 14 after removal of the adhesive-containing layer, identified as felt in this example.

Application of thin metal layer 36 may be accomplished by any deposition process which permits metal to contact the substrate tip 14 without affecting the physical contact between particles 20 and tip 14. One method of applying metal layer 36 is by electroless plating metal into the region between tip 14 and adhesive layer 32. However, the preferred method of application is complete immersion of blade tip 14 in an electroplating bath. Tip 14 of blade 10 is then electroplated, preferrably with a metal selected from the group consisting of nickel or cobalt. The thickness of metal layer 36 after electroplating is from about 0.1 to about 0.6 mils. Because the abrasive particles 20 are non-conducting in the preferred embodiment, no metal is deposited on them as a result of electroplating.

Referring now to Fig. 6, after application of metal layer 36, felt layer 30 having adhesive layer 32 may be removed from contact with abrasive particles 20. Because particles 20 are mechanically trapped by metal layer 36, felt layer 30 may be peeled back. However, other methods of removal of particles 20 from adhesive layer 32 may be utilized, so long as the bond between particles 20 and metal layer 36 remains undisturbed. For example, a suitable solvent may be introduced between felt layer 30 and metal layer 36 to dissolve adhesive layer 32, thereby allowing removal of felt layer 30.

After the removal of felt layer 30 and attached adhesive layer 32, abrasive particles 20 are in marked relief from thin metal layer 36 deposited over tip 14 as shown in Fig. 7. Because the bond between particles 20 and layer 36 is insufficient for the desired application, it is necessary to apply a matrix material over particles 20 before the abrasive tip can be effective in contact applications. Although the metal matrix may be any metal or alloy, it is preferred that the metal matrix be a metal or alloy which includes prealloyed powder or particles. To accomplish the application of the metal matrix material, fine particles of prealloyed powder are mixed in an electroplating solution of a metal or alloy. The fine prealloyed powder particles and solution readily flow into the space between the abrasive particles. The prealloyed powder particles are selected and applied in the appropriate volume fraction with the plating solution so that the metal matrix, after a suitable thermal treatment has the desired chemical composition. For example, a suitable volume fraction of NiCrAlY or CoNiCrAlY powder particles, up to about 60%, are mixed in a solution of cobalt and are subsequently entrapped in a matrix of cobalt. Alternatively, CoCrAlY particles are mixed in a solution of nickel and are subsequently entrapped in a matrix of nickel. The turbine blade tip is heat treated so that the metal matrix having the entrapped powder particles is homogenized by a diffusion heat treatment, thereby yielding a homogeneous matrix having the desired chemical composition.

The second metal or alloy having fine prealloyed powder particles is deposited over thin metal layer 36 and abrasive particles 20 to form a metal containing fine prealloyed powder particles surrounding abrasive particles 20, pr f rably using co-electrodeposition. Co-electrod position, dev loped by Bristol Aeroj t Limited, is described in U.S. Patent No. 4,305,792 incorporated herein by reference. In this process, the article to be coated is placed in a barr l together with the particles, and the barrel is placed in a plating bath and rotat d therein. The barrel has an opening covered by a cover which is pervious to the plating solution, but impervious to the

particles. The article is thus flowed over by solution within the barrel which can have a high concentration of particles, but there are no particl s in the part of the bath outside the barrel. The proc ss may be electroless or electrolytic. The depositing of the matrix of this invention may be accomplished by any suitable co-electrodeposition technique.

This second metal is applied over the abrasive particles in relief and the first thin metal layer 36. It is applied as a fine powder-containing plating solution in which the solution preferably is selected from the group of Co, and Ni, and is usually the same metal as the first thin layer The prealloyed, fine powder in the plating solution is a MCrAlY powder wherein M is an element selected from the group of Co, Ni and combinations thereof.

After deposition of the second metal containing the prealloyed fine powders, the second metal and particles may completely envelop particles 20 or may leave abrasive particles 20 in slight relief as shown in Fig. 1. The preferred thickness of second metal matrix 18 is approximately 60 to 70% of the average size of abrasive particles 20. For example, when the preferred particle size of about 5 to 6 mils is selected, the preferred second metal deposit thickness is from about 3 to about 4.5 mils. The preferred method of depositing second containing fine prealloyed powder particles (not shown) over abrasive particles 20 and thin layer 36 to form abrasive tip 16 is by co-electrodeposition.

A single layer of abrasive particles 20 is enveloped in a first thin metal layer 36 on top of which is deposited a second metal matrix 18 having prealloyed fine powder or particles (not shown). In order to form an abrasive tip 16 having abrasive particles embedded in a uniform metal matrix material 18 on tip end 14 of turbine blade 10, it is necessary to homogenize both the first thin metal layer 36, and the fine alloying powder-containing second metal layer. The homogenizing is accomplished by a homogenizing thermal treatment which must be for a sufficient time and at a sufficient temperature to achieve a substantially uniform alloy composition throughout the metal matrix 18 and thin metal layer 36 applied onto tip end 14, without adversely affecting the substrate material.

In the following examples, the volume fraction of pre-alloyed powder is typically about 60% the co-electrodeposited materials, the metal solution comprising the balance. This volume fraction will vary depending upon the final desired composition of the metal matrix, the metal solution composition and the alloy powder composition.

In a preferred embodiment, second metal matrix 18 may be Ni or Co, containing a MCrAlY powder, both the metal and powder selected so as to be compatible with thin metal layer 36. Thus, when thin metal layer 36 is selected from the group consisting of Ni and Co, the metal of the second metal matrix is also selected from the group Ni and Co, and MCrAlY alloy powder is chosen such that M is selected from the group of elements consisting of Co and Ni. Most preferably, first metal layer 36 and the second metal are the same element, either both Ni or both Co, and M of the MCrAlY is the remaining element (i.e., when second metal is Co, the powder is NiCrAlY) or a combination of Ni and Co i.e., NiCoCrAlY.

EXAMPLE 1

After application of a first cobalt thin layer 36 by electrodeposition and fine CoNiCrAlY powders in a second cobalt layer over the first thin layer by co-electrodeposition, thereby surrounding abrasive particles 20 on the tip of a Rene' 80 turbine blade, the blade is heat treated in an inert gas atmosphere or vacuum for about 4 -8 hours at about 1925-1950°F. The metal composition is initially essentially 100% Co and incidental elements which do not adversely affect the composition while the composition of the prealloyed CoNiCrAlY powder is, by weight, about about 54% Ni, about 32% Cr, about 13.5% Al, about 0.8 Y, and incidental elements which do not adversely affect the alloy powder. The heat treatment substantially homogenizes the metal matrix 18 surrounding abrasive particles 20, so that the composition of metal matrix 18 after heat treatment is, by weight, about 31-33% Ni, about 19-22% Cr, about 7-9% Al, about 0.35-0.65% Y, and the balance Co and small amounts of incidental elements which do not adversely affect the alloy.

EXAMPLE 2

After application of a first cobalt thin layer 36 by electrodeposition and fine CoNiCrAlY powders in a second cobalt layer by co-electrodeposition over the first thin layer, thereby surrounding abrasive particles 20 on the tip of a Rene' N5 turbine blade, the blade is heat treated in an inert gas atmosphere or vacuum for about 2-4 hours at about 1975-2050°F. The metal composition is initially essentially 100% Co and incidental elements which do not adversely affect the alloy, while the composition of the fine prealloy d powder is, by weight, about about 54% Ni, about 32% Cr, about 13.5% Al, about 0.8 Y, and incidental elements which do not adversely affect the alloy powder. Th heat tr atm nt substantially homogenizes metal matrix 18 surrounding the abrasiv particles, so that the composition of metal matrix 18 after heat treatment is, by weight, about 31-33% Ni, about

19-22% Cr, about 7-9% Al, about 0.35-0.65% Y, and the balance Co and small amounts of incidental elements which do not adversely affect the alloy.

EXAMPLE 3

After application of a first cobalt thin layer 36 by electrodeposition, and fine powders having a composition by weight of about 20% Co, 10.2% Al, 10.7% Ta, 11.3 % Cr, 2.5% Hf, 4.7% Re, 0.2% C, 8.3% W and the balance Ni and incidental impurities in a second nickel layer by co-electrodeposition over the first thin layer, thereby surrounding abrasive particles 20 on the tip of a Rene' N5 turbine blade, the blade is heat treated in an inert gas atmosphere or vacuum for about 2-4 hours at about 2000-2075°F. This heat treatment substantially homogenizes metal matrix 18, thin layer 36 and the fine powder so that the composition of the metal matrix after heat treatment is the composition of Rene' 142, Table 1.

EXAMPLE 4

After application of a first cobalt thin layer 36 by electrodeposition, and fine powders having a composition by weight of about 6.7% Co, 10% Al, 8.3% Ta, 15% Cr, 1.5% Hf, 2.5% Mo, 2.3% Re, 0.03% Zr and the balance Ni and incidental impurities in a second nickel layer by co-electrodeposition over the first thin layer, thereby surrounding abrasive particles 20 on the tip of a Rene' N5 turbine blade, the blade is heat treated in an inert gas atmosphere or vacuum for about 2-4 hours at about 2000-2075°F. The heat treatment substantially homogenizes metal matrix 18, thin layer 36 and the fine powder so that the composition of the metal matrix after heat treatment is the composition of PS6MY, see Table 1.

EXAMPLE 5

After application of a first cobalt thin layer by electrodeposition and fine powders having a composition by weight of about 16.7% Co, 10.8% Al, 10% Ta, 30% Cr, 0.83% Hf, 3.3% Re, 0.07% C, 0.02% Zr and the balance Ni and incidental impurities in a second nickel layer by co-electrodeposition over the first thin layer, thereby surrounding abrasive particles 20 on the tip of a Rene' N5 turbine blade, the blade is heat treated in an inert gas atmosphere or vacuum for about 2-4 hours at about 2000°-2075°F. This heat treatment substantially homogenizes metal matrix 18, thin layer 36 and the fine powders so that the composition of the metal matrix after heat treatment is the composition of BC-53, see Table 1.

Table 1
Nominal Composition

	PS6MY	Rene' 142	BC-53
Ni	Bal.	Bal.	Bal.
Co	4	12	10
Al	6	6.1	6.5
Ta	5	6.4	6
Cr	9	6.76	18
Hf	0.9	1.49	0.5
Mo	1.5	---	0
Re	1.4	2.84	2.0
C	0	.11	0.05
Zr	0.02	---	0.01
W	---	5	---

While the process of the present invention eliminates the necessity for providing coated abrasive particles, if desired particles 20 may optionally be coated with a coating, such as a diffusion barrier coating, prior to placing the particles in contact with adhesive layer 32. However, it is preferred to use nonconductive and nonsilicon-bearing particles, such as alumina (Al_2O_3).

Because the embodiment of the invention shown in Fig. 1 is thin, being comprised of a single layer of abrasive particles 20 embedded in a metal matrix 18, it is expected that abrasive tip 16 will be removed from tip 14 of blade 10 in a relatively short time as compared to overall blade life. In such a case, it may be desirable to optionally coat tip 14 with an environmentally resistant material prior to application of the abrasive tip. In such a case, the abrasive tip is applied by the process of the present invention over the environmentally resistant material, in which case the environmentally resistant material is substituted for the substrate in the above description of the invention. A commonly used environmentally resistant material has a nominal composition of, by weight, of about 33% Ni, about 23% Cr, about 4% Al, about 0.5% C, about 3% W, about 33% Co, about 3% Ta, about 0.75% Si. along with incidental impurities. This composition is described in U.S. Pat. No. 4,227,703 issued Oct. 14, 1980, which is hereby incorporated by reference. However, this environmentally resistant undercoat is provided by way of example, and is not meant to limit application of the long life abrasive tip of the present invention solely over this environmentally resistant undercoat. A turbine blade having an environmentally resistant layer 44 overlaying tip 14 is shown in Fig. 8.

If early removal of the thin abrasive tip is undesirable during engine operation, the method of, the present invention can be used to apply multiple layers of particles, so that even if the initial layer of particles is worn off the tip, additional layers of particles remain so that additional material can be abraded from the shroud, if necessary. Referring now to Fig. 9, a turbine blade 80 having an abrasive tip 82 with two rows of abrasive particles, 84 and 86 embedded in a metal matrix 88 is depicted. Abrasive particles 84 in the layer closest to blade tip 90 ar coplanar and parallel to the plane of abrasive particles 86 forming the layer furthest from blade tip 90. Although particles 84 and 86 are shown as being about the same size, it may be desirable to size the particles such that particles 86 are larger, which is desirabl during three-body-abrasive wear which occurs early in engine operation, while particles 84, which are smaller, will remain after the layer containing particles 86 has

worn away. The smaller particles in the layer closer to the tip will be more effective during the adhesive wear phases which may occur during later stages of engin op ration.

In light of the foregoing discussion, it will be apparent to those skilled in the art that th present invention is not limited to the embodiments, methods and compositions herein described. Numerous modifications, changes, substitutions and equivalents will now become apparent to those skilled in the art, all of which fall within the scope contemplated by the invention.

Claims

1. A method for applying an abrasive layer to a metallic substrate, the abrasive layer comprised of abrasive particles in a metal alloy matrix comprising the steps of :
   (a) selecting abrasive particles of about size and shape to maximize volume content of the particles;
   (b) physically contacting the abrasive particles to the substrate surface;
   (c) while maintaining the particles in contact with the substrate surface, depositing a first thin layer of metal onto the substrate surface, thereby adhering the abrasive particles to the substrate surface;
   (d) applying a second metal containing fine prealloyed powders by co-electrodeposition over the abrasive particles and the first thin layer of metal; and,
   (e) thermally treating the abrasive-layered substrate to homogenize the first thin layer of metal and the second metal containing prealloyed powders to form a substantially homogeneous metal alloy matrix.

2. A method for applying an abrasive layer to a substrate, the abrasive layer comprised of at least one discrete layer of environmentally resistant abrasive particles in a metal matrix, the abrasive particles in a discrete layer being coplanar, comprising the steps of:
   (a) selecting abrasive particles of approximately the same size and shape;
   (b) physically contacting the abrasive particles to the substrate surface;
   (c) while maintaining the particles in physical contact with the substrate surface, depositing a first thin layer of metal onto the substrate surface, thereby adhering the abrasive particles on the substrate surface;
   (d) applying a second metal containing fine prealloyed powders by co-electrodeposition over the abrasive particles and the first thin layer of metal; and
   (e) heat treating the substrate to homogenize the first thin layer of metal and the second metal containing prealloyed powder to form a homogeneous uniform metal matrix.

3. The method of claim 2 wherein the step of physically contacting the abrasive particles to the substrate surface further comprises:
   applying the abrasive particles to a surface of a material having an adhesive layer;
   removing excess abrasive particles from the adhesive layer;
   placing the abrasive particle containing adhesive layer against the substrate surface so that the abrasive particles contact the substrate surface; and
   maintaining the abrasive particles in contact with the substrate surface.

4. The method of claim 2 wherein the step of selecting abrasive particles further includes selecting approximately cubic-shaped abrasive particles having a minimum edge dimension of about 2 mils and a maximum edge dimension of about 15 mils.

5. The method of claim 4, wherein the aspect ratio of the abrasive particles is about 1.

6. The step of claim 5 further including selecting approximately cubic-shaped abrasive particles having an edge dimension of about 5 to about 6 mils.

7. The step of claim 5 wherein the step of selecting abrasive particles further includes selecting abrasive particles made by the sol-gel process.

8. The method of claim 2 wh rein the step of depositing the first thin metal layer includes electroplating th first thin metal over the substrate surface.

9. The method of claim 2 wherein the step of depositing the first thin metal layer includes electroless plating

the first thin metal over the substrate surface.

10. The method of claim 2 wherein the step of depositing the first thin metal layer further includes depositing the first thin layer of metal selected from the group consisting of Ni and Co onto the substrate surface to a thickn ss of about 0.1 to about 0.6 mils.

11. The method of claim 3 wherein the step of selecting abrasive particles includes selecting approximately cuboidal alumina particles having an edge size of about 0.005 to about 0.006 inches.

12. The method of claim 2 further including the step of encapsulating the abrasive particles with a diffusion barrier coating after the step of selecting abrasive particles and before the step of contacting the particles to the substrate surface.

13. The method of claim 2 wherein the step of depositing a second metal further includes co-electrodepositing a second metal solution having fine prealloyed powder particles.

14. The method of claim 12 wherein the step of co-electrodepositing includes co-electrodepositing a second metal selected from the group consisting of nickel, and cobalt and the fine prealloyed powder is selected from the group consisting of NiCrAlY, CoNiCrAlY and CoCrAlY.

15. A method for applying an abrasive tip to a turbine blade having a first end adapted for attachment to a turbine disk, and a second tip end, the abrasive tip comprised of at least one discrete layer of oxidation-resistant and corrosion-resistant abrasive particles in a metal alloy matrix, the particles in a discrete layer being coplanar, comprising the steps of :
(a) selecting abrasive particles of approrimately the same size and shape;
(b) applying the abrasive particles to a surface of a layer of felt having an adhesive;
(c) removing excess abrasive particles from the surface of the layer of felt having the contact adhesive;
(d) placing the tip end of the turbine blade in physical contact with the abrasive particles adhering to the layer of felt having the adhesive;
(e) securing the felt to the tip end of the turbine blade;
(f) immersing the tip end of the turbine blade in an electroplating bath;
(g) while maintaining the abrasive particles in mechanical contact with the the turbine blade tip end, electroplating a first thin layer of metal onto the tip end of the turbine blade, thereby causing the abrasive particles to adhere to the tip end of the turbine blade;
(h) removing the layer of felt;
(i) applying a solution of a second metal containing fine prealloyed powder particles by co-electrodeposition over the abrasive particles and the first thin layer of metal on the substrate surface; and
(j) heat treating the blade so as to homogenize the first thin layer of metal and the second metal containing fine prealloyed powder particles to form a substantially homogeneous metal matrix.

16. The method of claim 15 further including the step of encapsulating the abrasive particles with a diffusion barrier coating after the step of selecting the abrasive particles and before the step of applying the particles to a surface of a layer of felt.

17. The method of claim 15 further including a step of coating the tip end of the turbine blade with an environmentally resistant material prior to the step of placing the tip end of the blade in contact with the abrasive particles.

18. The step of claim 15 wherein the step of selecting abrasive particles includes selecting approximately cuboidal-shaped abrasive particles having a minimum edge dimension of about 5 to about 6 mils and wherein the abrasive particles are made by the Sol-Gel process.

19. The method of claim 15 wherein the step of electroplating includes electroplating a metal selected from the group consisting of cobalt and nickel.

20. The method of claim 15 wherein the step of applying a second metal includes applying a second metal compatible with the first electroplated m tal.

21. The method of claim 15 wherein the step of applying a second metal includes applying a metal selected from the group consisting of Ni and Co, and wher in the fine prealloyed powder particles ar selected from the group consisting of NiCrAlY, CoNiCrAlY and CoCrAlY.

22. A method for applying an abrasive tip to a turbine blade having a tip end, the abrasive tip comprised of at least one discrete layer of environmentally resistant abrasive particles in a Rene' 142 metal matrix of the abrasive particles in a discrete layer being coplanar, comprising the steps of:
(a) selecting abrasive particles having about the same aspect ratio;
(b) physically contacting the abrasive particles to the tip end of the turbine blade;
(c) while maintaining the particles in physical contact with the tip end of the turbine blade, depositing a thin layer of Co onto the blade tip end, thereby adhering the abrasive particles to the tip surface;
(d) co-electrodepositing a solution of Ni and fine pre-alloyed powders over the abrasive particles and the layer of Co, the fine pre-alloyed powders selected so that after substarted homogenization the metal matrix is Rene' 142.
(e) heat treating the blade to substantially homogenize the prealloyed powder and Ni to form a Rene' 142 matrix.

23. A method for applying an abrasive tip to a turbine blade having a tip end, the abrasive tip comprised of at least one discrete layer of environmentally resistant abrasive particles in a PS6MY metal matrix, the abrasive particles in a discrete layer being coplanar, comprising the steps of:
(a) selecting abrasive particles having about the same aspect ratio;
(b) physically contacting the abrasive particles to the tip end of the turbine blade;
(c) while maintaining the particles in physical contact with the tip end of the turbine blade, depositing a thin layer of Co onto the blade tip end, thereby adhering the abrasive particles to the tip surface;
(d) co-electrodepositing a solution of Ni and fine pre-alloyed powders over the abrasive particles and the layer of Co, the fine pre-alloyed powders selected so that after substarted homogenization the metal matrix is PS6MY.
(e) heat treating the blade to substantially homogenize the prealloyed powder and Ni to form a PS6MY matrix.

24. A method for applying an abrasive tip to a turbine blade having a tip end, the abrasive tip comprised of at least one discrete layer of environmentally resistant abrasive particles in a BC-53 metal matrix, the abrasive particles in a discrete layer being coplanar, comprising the steps of:
(a) selecting abrasive particles having about the same aspect ratio;
(b) physically contacting the abrasive particles to the tip end of the turbine blade;
(c) while maintaining the particles in physical contact with the tip end of the turbine blade, depositing a thin layer of Co onto the blade tip end, thereby adhering the abrasive particles to the tip surface;
(d) co-electrodepositing a solution of Ni and fine pre-alloyed powders over the abrasive particles and the layer of Co, the fine pre-alloyed powders selected so that after substarted homogenization the metal matrix is BC-53.
(e) heat treating the blade to substantially homogenize the prealloyed powder and Ni to form a BC-53 matrix.

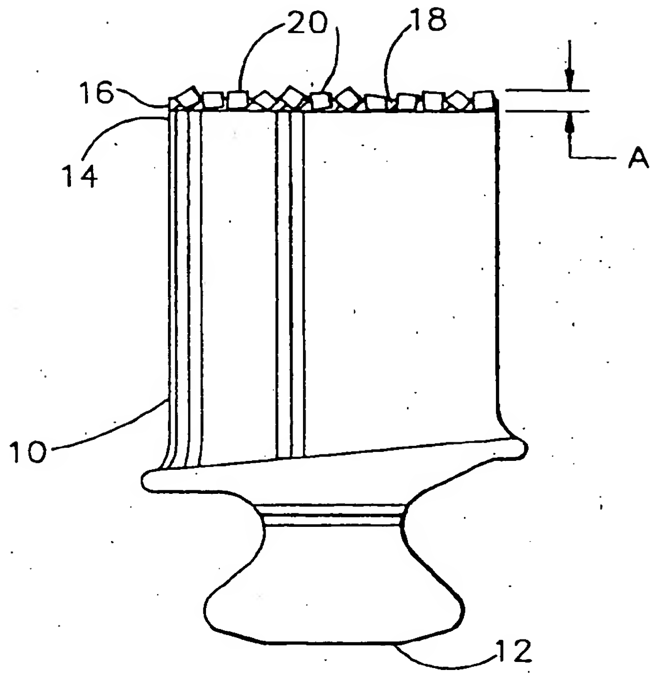

FIG. 1

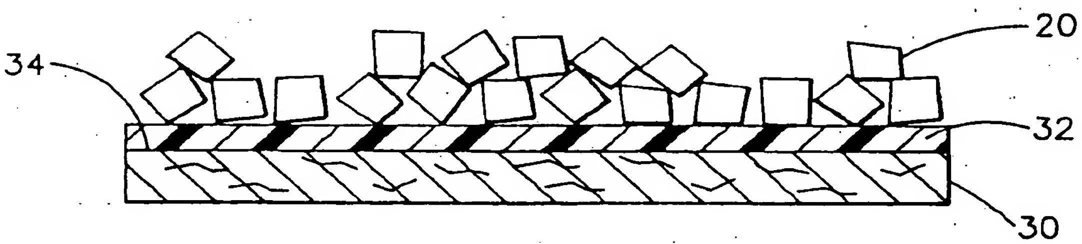

FIG. 2

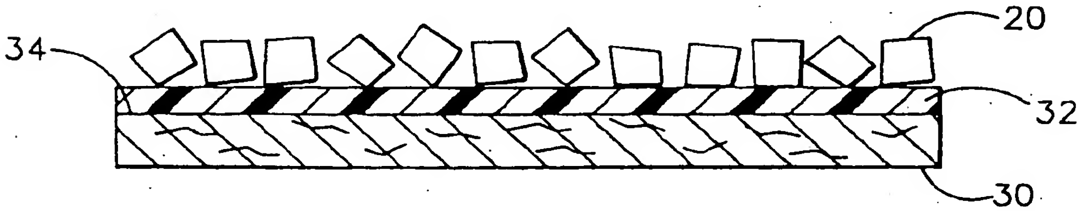

FIG. 3

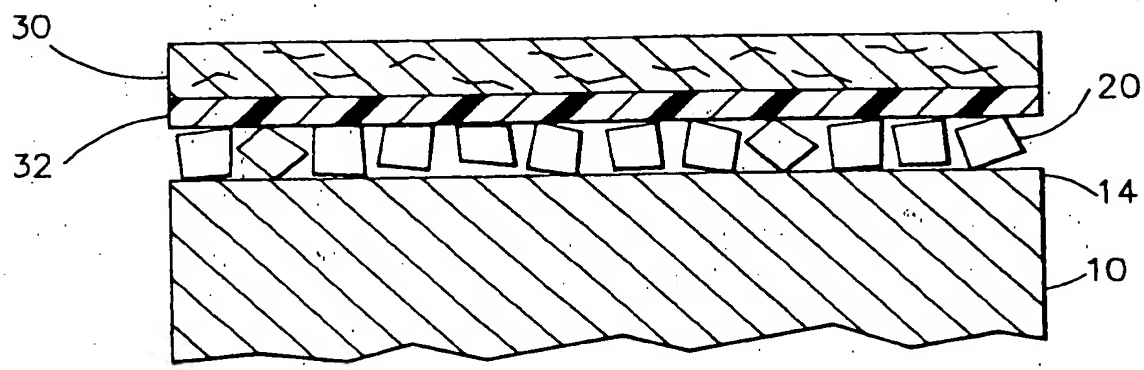

FIG. 4

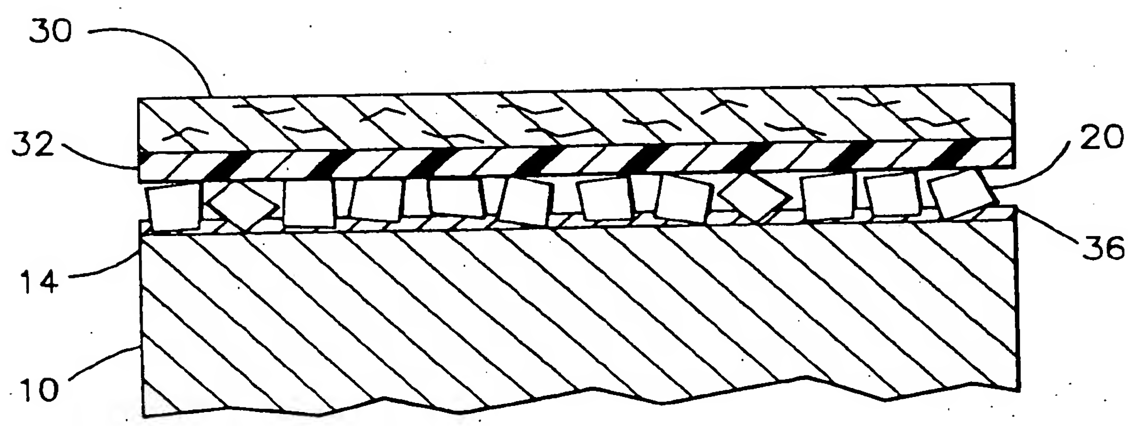

FIG. 5

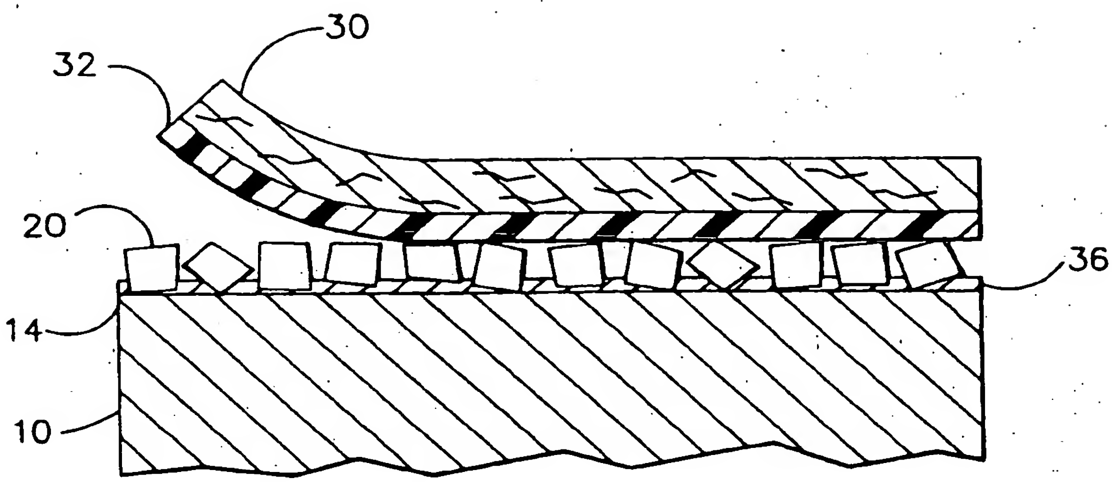

FIG. 6

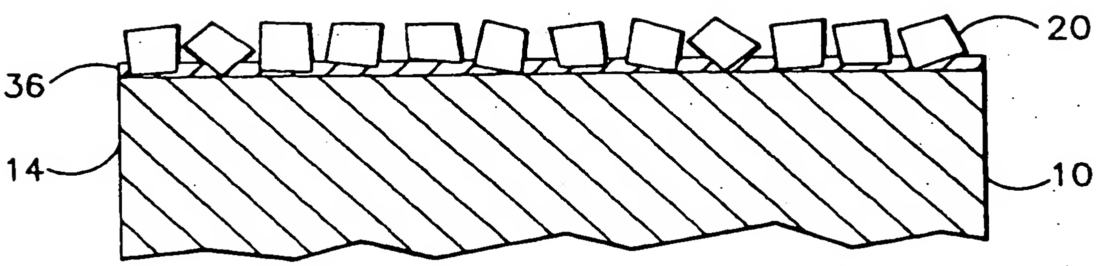

FIG. 7

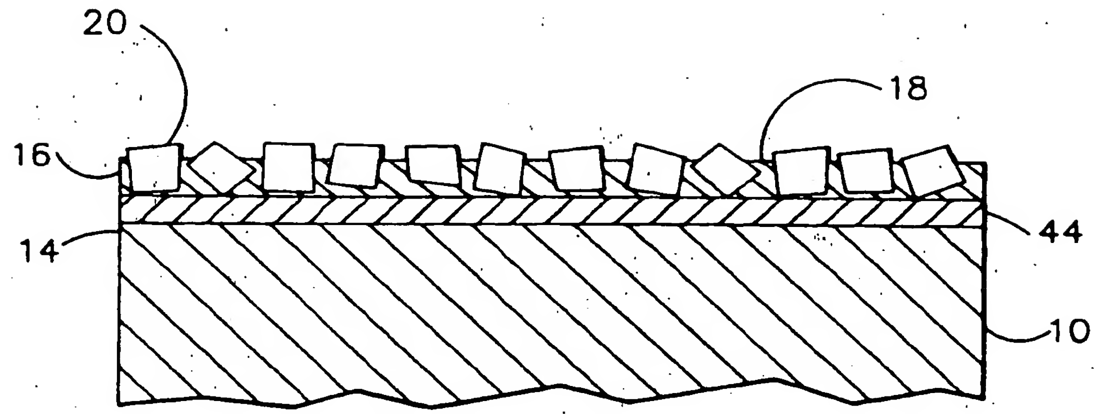

FIG. 8

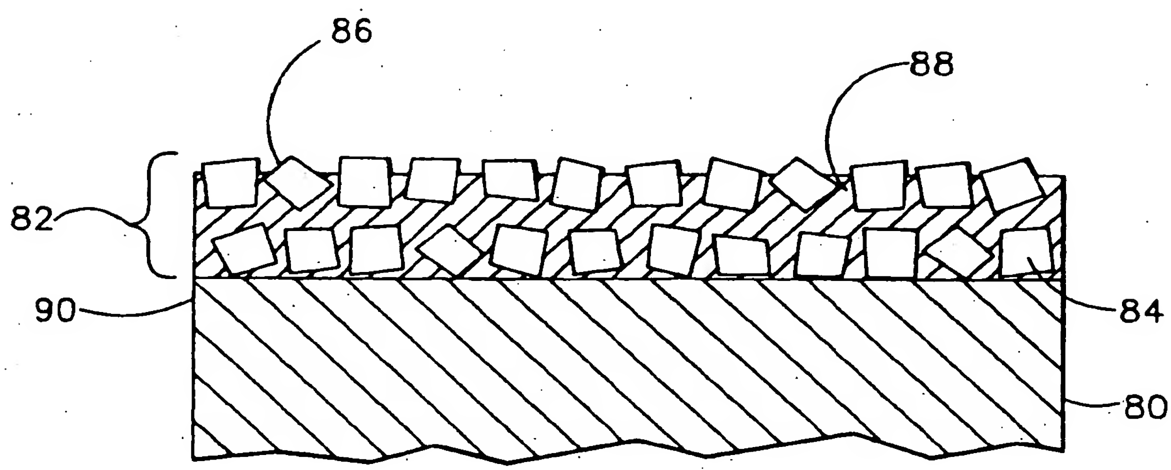

FIG. 9

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 91 30 9998

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	GB-A-2 162 201 (GENERAL ELECTRIC) * the whole document *	1--11, 13-15, 19-24	C25D15/00 F01D5/20
A	GB-A-2 167 446 (BAJ) * the whole document *	1-11, 13-15, 17-24	
A,D	US-A-4 744 725 (MATARESE) * column 3, line 5 - column 12, line 24 *	1-24	
A	US-A-4 818 833 (FORMANACK) * the whole document *	1-24	
X	US-A-3 980 549 (GRUTZA) * column 3, line 38 - column 6, line 67 *	1-6,11, 15,18, 22-24	
P,X	EP-A-0 443 877 (BAJ) * the whole document *	1-24	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

C25D
F01D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	05 FEBRUARY 1992	IVERUS D.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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E : earlier patent document, but published on, or after the filing date
D : document cited in the application
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